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TRANSITIONING TO UNMANNED COMBAT AERIAL VEHICLES

by

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ABSTRACT

The Air Force is currently developing Unmanned Combat Aerial Vehicles (UCAV). The UCAV is projected for initial testing by 2010. However, after reviewing the Office of Secretary of Defense's Unmanned Aircraft Systems Roadmap for 2005–2030; obtaining squadrons of UCAVs will cost billions of dollars and require decades to produce. The United States cannot afford to wait decades for unmanned weapons. Technology is spreading fast. Third world countries without stable economies and non-state actors are able to obtain/develop sophisticated weapons that are capable of easily destroying tactical aircraft. With sophisticated weapons obtainable, the risk of losing people in air combat is increasing significantly and that in turn is creating a level playing field for prospective U.S. adversaries. Unmanned weapons technology can help America retain its military edge. However, since unmanned warfare capability is still decades away and is a multi-billion dollar project, America needs a quick fix. *This study will argue that the most effective way to decrease risk-of-life and budget costs is to introduce F-16 Unmanned Aerial Systems (UAS) aircraft for combat.* This thesis will answer the question: How can the government seize the unmanned aircraft advantages and decrease defense spending until the UCAV is operational? The answer to this question will illustrate how an effective F-16 UAS force can synchronize resources to properly complete UCAV development while instantly reducing risk of life.

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I. INTRODUCTION

A. THE FUTURE OF WAR

One can only imagine what the future of war is going to look like. Many fiction and non-fiction authors feel that future wars will be fought at home by the technologically advanced. Imagine, by way of example, a country with a million-man militia and fleets of air, sea, and land craft — the largest standing military in the world. Imagine, too, that this country's neighbor has ten thousand robots and unmanned air, sea, and land vehicles that can outmaneuver most defenses and easily target vital points of interest. Even though the human militia outnumbers its foe 100:1 and was given an 80% chance of successfully destroying the unmanned army, would the country be willing to allow 10,000, 100,000, or 500,000 troops to die while their enemy loses none? Is it worth losing thousands of people and billions of dollars in technology and infrastructure while their foe loses nothing but an unmanned arsenal that can be easily rebuilt?

The thought that unmanned weapon systems will replace manned ones is coming to fruition. The U.S. Department of Defense has created roadmaps for each unmanned system that will replace the current U.S. inventory of land, sea, and air vehicles. This family of unmanned systems technology and capabilities will share similar attributes and operate in close coordination as a team (Office of Sec. Def., Aug 2005*, pg 76).* The unmanned aerial systems (UAS) mission roadmap (See Table 1) provides a timeline in which each air mission and aircraft will be replaced by a UAS. According to the roadmap, unmanned aircraft will replace most fighters, cargo, passenger, and other mission aircraft by the year 2030. One of the primary benefits of unmanned technology is the significantly reduced loss of life and money.

The roadmap may seem very aggressive; but it will still take decades and billions of U.S. dollars to replace the current air inventory. The United States cannot afford to wait decades for unmanned weapons. Technology is spreading fast. Third world countries without stable economies are able to obtain/develop sophisticated weapons that are capable of destroying U.S. aircraft. With sophisticated weapons easily obtainable, the

risk of losing people in air combat is increasing significantly and that in turn is creating a level playing field for perspective U.S. adversaries.

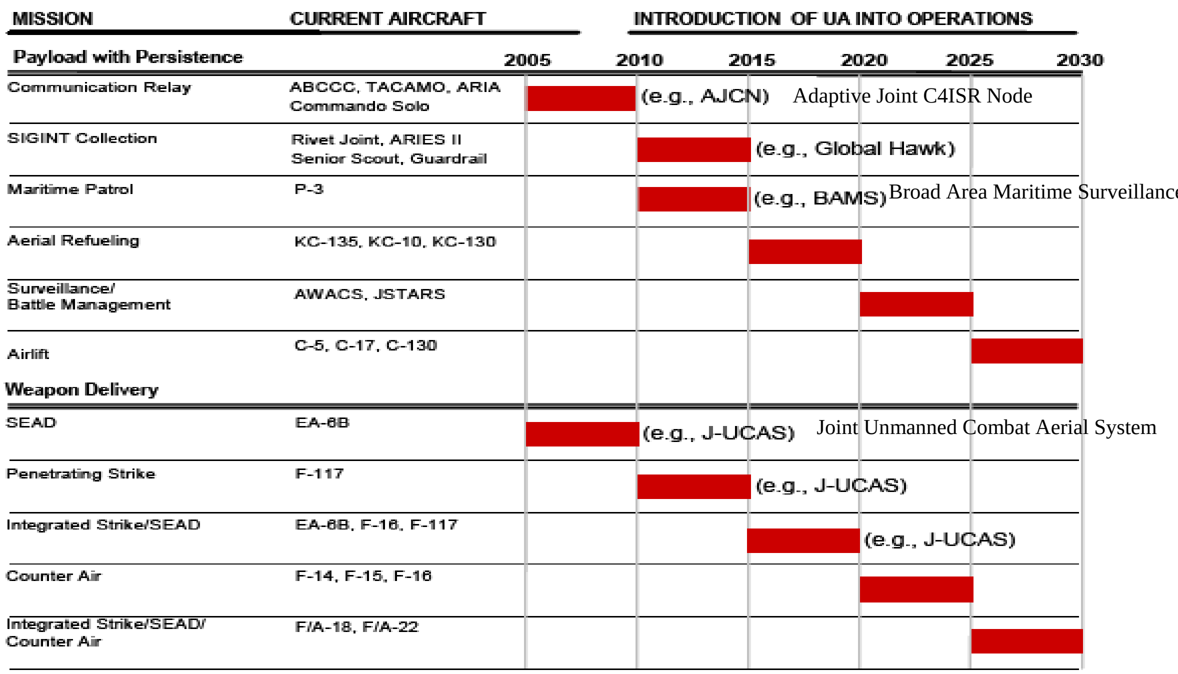

Table 1. UAS Missions Roadmap (Office of Sec. Def., Aug 2005.)

Unmanned weapons technology can help America retain its military edge. Since, however; unmanned warfare capability is still decades away, America needs a quick fix. *This study will argue that the most effective way to decrease risk of life and budget costs is to introduce F-16 UASs for combat until a future unmanned weapon system can replace the inventory in Table 1.*

Before the discussion of F-16 UAS aircraft can be entertained, the advantages and disadvantages of UASs must be established. By providing this information, one can reasonably understand why the Department of Defense is in favor of replacing manned weapon systems.

B. WHAT'S GOOD ABOUT UNMANNED AIRCRAFT?

According to Joint Publication 1-02 DoD Dictionary, the definition of an Unmanned Aerial System (UAS) is:

> A powered, aerial vehicle that does not carry a human operator uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload. Ballistic or semi ballistic vehicles, cruise missiles, and artillery projectiles are not considered unmanned aerial vehicles (Office of Sec. Def., Dec 2002, *pg 16).*

Unmanned Aerial Systems have "a history as long as that of aviation itself" (Armitage, 1988, p. 1). The first live experiments with unmanned aircraft started in the United Kingdom in 1917 when a simple pilotless aircraft, using a 35HP engine, was developed by Grandville Bradshaw (Armitage, 1988, p. 1). Since then, UASs have advanced dramatically. These advancements have finally reached a point that allows UAS theories to become reality. There is a common theory that UASs are better suited for the "dull, dirty, or dangerous" missions than manned aircraft (Office of Sec. Def., Aug 2005, *pg 1).* Military Aerospace Technology online defines the dull, dirty, or dangerous as:

> Dull—as in patrolling no-fly zones or very long intelligence, surveillance and reconnaissance (ISR) missions; the UAS is just as alert in the last hour of its patrol as it is in the first hour. Dirty—as in operations in airspace potentially contaminated with biological or chemical weapons. And dangerous—as in electronic attack missions, often performed early in a battle while the enemy's air defenses pose a serious threat (Barr, 2005).

These three attributes make the use of unmanned flight a viable alternative to manned flight. During the dull missions the alertness of machines is superior to that of humans, and for the dirty and dangerous, the political and human cost is lower, should the aircraft be lost. (Office of Sec. Def., Aug 2005, *pg 2*). Even though the dull, dirty, and dangerous theory is an excellent argument for UAS development; there are other primary factors for UAS development that are not directly addressed. These factors are risk-of-life, technological capabilities, decreased budget costs, and range and endurance capabilities.

1. Risk-of-Life

Risk-of-life is a significant benefit that cannot be overlooked. UASs literally bring the decision factor to risk a pilot's life to zero. No matter how easy or difficult the task, political leaders would never have to consider the risk-of-life dilemma again. The dull, dirty, and dangerous theory only focuses on three mission areas in which UASs can prove advantageous, but in the risk-of-life decision, UASs can outweigh any mission. For example, according to the U.S. Air Force Legal Services Agency, 20 Class A aerospace mishaps occurred during Fiscal Year 2005 (Air Force Safety Center, 2006). A Class A mishap is an accident that results in fatality or total permanent disability, loss of an aircraft, or property damage of $1 million or more. Of those 20 mishaps, approximately 12 are easily identified as training missions and an additional 5 are identified as UASs, 4 of which were in combat. This means that 85% of all Class A mishaps are due to training missions and only 8.3% of those Class A training mishaps are from unmanned aircraft. "Typically 80 % of the useful life of today's combat aircraft is devoted to pilot training and proficiency flying, requiring longer design lives than would be needed to meet combat requirements" (Pike, Dec. 2005). Without the requirement to fly sorties to retain pilot proficiency, UASs will fly less frequently. As a result, if the USAF were to replace all mission aircraft with UASs, there would be an 89.7% decrease in Class A accidents within the USAF. In short, UASs have the advantage in all mission considerations when the loss-of-life factor is considered.

2. Technological Capabilities

Technology is another area in which UASs have the advantage over manned aircraft. This is caused by limiting factors that the human physiology prevents certain capabilities from being utilized. Currently under development is the X-45 Unmanned Combat Aerial Vehicle (UCAV). It is a future UAS that will have fighter-like performance characteristics that can provide over 10-hours of endurance while carrying a payload of bombs and missiles capable of using Global Positioning System (GPS) and laser-guided technologies (Stout, 2005 pg. 31). Additionally, the X-45 UCAV will be virtually undetectable by radar. This will be achieved via stealth capabilities provided by a "miniscule radar signature" (Brasher, 2005 pg. 37). The X-45 UCAV has the benefit of eliminating the need for a cockpit which gives it the stealth advantage over existing

piloted stealth aircraft. The "cockpit is a major source of radar return on manned aircraft, even stealthy ones" (Brasher, 2005 pg. 37). Additionally, the X-45 UCAV will be able to withstand over 30 Gs of force during maneuvers. One G-force is equivalent to the gravitational pull of the earth. Most fighter pilots with years of training can withstand a maximum of 9 Gs for 10 seconds. An increase of 21 G-forces will allow the UASs to achieve maneuvers never before imagined. Finally, without the pilot there are multiple of unnecessary for flight. These include an ejection seat, parachute, oxygen system, among others. By not requiring these systems, the UAS benefits from having less payload for life support and more for endurance, and technology enhancements, along with smaller size to avoid enemy detection. These advantages will reduce UAS maintenance requirements to half the current manned aircraft level.

3. Decreased Costs

Many critics feel that UAS research and development (R&D) costs are too high now that Congress is looking to significantly reduce spending. According to Air Force Magazine, UASs "are now commanding some $2 billion a year of the DOD budget, UAVs will account for about $13 billion in production funding through the end of the Pentagon's six-year plan" (Tirpak, Nov 2005). When one examines the data more closely one will find that $2 billion a year is smaller than many other projects in the works. For example, the F-22 cost over $38 billion in 1990 dollars for R&D alone. This excludes the fact that one F-22 will cost $211 million to field and requires a pilot with many years of experience. The X-45 UCAV is estimated to cost $8 million each, and will be more advanced than the F-22.

Reusability is the key advantage the UAS has over cruise missiles, which can be used only once (Thompson, 2000). Many military strategists feel cruise missiles are the answer to preventing risk to pilots. This was evident in Kosovo/Operation Allied Force. The tomahawk cruise missile cost between $1.1 and $1.2 million each in 2000 dollars (Thompson, 2000). In contrast, an $8 million UAS with over ten weapons on board could prove more cost-effective than a cruise missile in a single flight, presuming that the UAS is able to destroy ten targets with its weapon arsenal. This estimate also allows for a conservative $3 million for bombs, fuel, and one year of maintenance support (Thompson, 2000).

4. Range and Endurance

With the aid of air refueling systems, the UAS is theoretically capable of limitless flight. Without a pilot in the cockpit, there is no need to land the aircraft except for maintenance problems and re-arming. However, if air refueling assets are unavailable, a UAS is still capable of longer flight times and ranges. This is due to less drag from the canopy and cockpit and more room to carry fuel. Some UASs are capable of flying for days over enemy territory (Thompson, 2000).

C. WHAT'S BAD ABOUT UNMANNED AIRCRAFT?

Unmanned aerial systems do have some disadvantages that need to be worked out. The primary disadvantages are bandwidth and jamming. Additionally, some critics feel that UASs have a higher probability of crashing, prevent a proper field of view, and eliminate the decision process from the cockpit. They is also pose an ethical dilemma that will be discussed in Chapter V of this thesis.

1. Bandwidth

There are primarily two basic approaches to implementing unmanned flight, unmanned autonomist flight and pilot-in-the-loop (Office of Sec. Def., Aug 2005, *pg 48*). There are many existing definitions for unmanned autonomous flight, but, for the purposes of this thesis I will define it as: An unmanned flight system with the ability to complete or abort a mission without human intervention. This definition refers to unmanned systems that have the ability to make strategic and tactical decisions on their own. Autonomous flight is an important factor in UAS technology since it would enable the UAS to complete its missions without intervention. As a consequence, bandwidth and jamming disadvantages would be significantly reduced. However, the 2005 UAS Roadmap indicates this type of technology will not be available until 2015-2020 (48). Since this thesis is addressing current technology the more relevant type of unmanned flight is pilot-in-the-loop. Pilot-in-the-loop will be defined as: an unmanned flight system that is under human control. This means that the unmanned aircraft will be completely under the control of a pilot from a location other than the aircraft. For purposes of this thesis, we will refer to UAS as always meaning pilot-in-the-loop

technology. The UAS requires communications technologies that can provide the ability to fly the aircraft. Some of these technologies are: 360 degree real-time visual access (video), manual control to fly the aircraft and utilize its weapons (data), and positioning capability (GPS). Communications technologies like these require, a lot of bandwidth. According to webopedia; bandwidth is: "The amount of data that can be transmitted in a fixed amount of time" (2006). Today, telephone lines, satellite dishes, and other forms of communications systems can only transmit a limited amount of bandwidth per-second. This is why bandwidth is a huge problem with UASs. Since bandwidth is limited, loss of UAS control can occur from latency, link loss, and/or poor video feeds. Additionally, the bandwidth problem limits the number of UASs that can be flown at the same time. Currently, time is the only fix to the bandwidth problem. The Office of the Secretary of Defense believes technology is increasing at an exponential rate and the demand for bandwidth will remedy itself in time. However, if UAS technology is to succeed, the bandwidth situation must be immediately addressed and fixed.

2. Jamming

UASs require bandwidth to control, orient, and push/receive data, which makes jamming a very effective tool. Jamming is an ability that allows one to interfere with the transmission of information from one point to another (Adamy, 2001, pg. 177). Jamming becomes effective when one can make a signal strong enough to prevent a system from recovering the required information from the desired signal (Adamy, 2001, pg. 177). It is a dangerous threat to all air, land, and sea systems that require some form of communications; however, it could be lethal to a UAS. If a UAS is properly jammed it could lose control and be destroyed. This is not necessarily a problem with a manned system because the pilot can still fly the aircraft without many of the aircrafts instruments. There are many ways to avoid/deter jamming from occurring, but this is a serious threat that could prevent a UAS from completing its mission. Engineers would need to develop a default system that would allow the F-16 UAS to retreat to a neutral position where control can be regained after a success jamming.

D. BONE YARD UAS

A bone yard UAS is an existing or retired fighter or bomber aircraft that has been converted into a remotely piloted aircraft. By no means is this new technology, but it is a new concept. Companies have been converting old weapons systems into target drones for decades. "The first pilotless Target drones were developed for the U.S. Army Air Force in the late 30s" (Airshots, 2001). When the Jet age arrived, the need for missile-based combat increased. This drove a need for target drones with realistic performance. Since then, companies have been converting small batches of early jet types for pilotless flight. British Aerospace (BAe) is one such company. It has converted over 500 F-86, F-100, F-5, F-106, and F-4 aircraft into drones (BAe systems, 2005, June). All drone aircraft are given the designator of Q to identify them as drones. BAe is currently developing QF-4s. It has already completed 175 (BAe systems, 2005, June). Conversion of each QF-4 takes around 18 weeks at Mojave Airport, California. On arrival, each Phantom is stripped down for inspection and modification. "On completion, the airframe is delivered to Tyndall for any additional installations and tests required" (Airshots, 2001).

Figure 1. QF-4E 68-0345 was the first conversion. (Airshots, 2001)

> The QF-4 is fully capable of Combat Air Maneuvering with or without a pilot. Missions can be fully automated from take off to landing, including 4g barrel rolls and 6g slices. The aircraft is also fully supersonic. Formations of up to 4 can be flown unmanned, relying on GPS systems to

> maintain spacing. These QF-4's are fully operational at both Tyndall and at Holloman AFB and is the only (known) full size target drone in use with the USAF at present (Airshots, 2001).

BAe is currently working on the last group of F-4s that will be converted into drones (BAe systems, 2005, June). The next phase of Q aircraft is going to be the F-16. More than 4,000 F-16s have been made and are used by two dozen countries (Schonauer, 2005, November). Of these 4,000 F-16s, the United States has bought over three quarters of them. The bone yard contains over 1,800 of these retired F-16 airframes (Dewitt and Vanhastel, 2006). Instead of developing QF-16s for missile testing, there is the prospect of developing them for combat. The "USAF can quickly provide a cost-effective unmanned military option by modifying bone yard or currently operational F-16 fighters into UASs" (Thompson, 2000). According to Michelle Burdick at BAe; "the F-16 drone/UAS could be developed and online within approximately 12-15 months" (Michelle Burdick, personal interview, January 26, 2006)

E. SUMMARY

Even though there are a few drawbacks, UASs are the future American aerial weapons system. However, the X-45 UCAV is still decades away. As a result, the USAF is planning to increase its manned combat fighting forces with multi-billion dollar investments that will be terminated when the X-45 UCAV is ready for combat. The F-16 UAS is a cheap alternative that could save lives and the American taxpayers well over 25 billion dollars. This thesis will make an in-depth cost comparison (Chapter II, F-16 UAS vs. an F-16 and F-22); will present a Nash arbitration model (Chapter III, F-16 UAS vs. the F-16 and F-22); and will consider use of the F-16 UAS in a real world scenario (Chapter IV, Kosovo/Operation Allied Force) with the intent of proving the F-16 UAS's worth.

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II. THE F-16 UAS

A. BACKGROUND

The American government is undergoing substantial budget cuts and needs to find the best avenues to decrease government spending within the Department of Defense. Consequently, the government is looking at the F-22 and F-35 manned fighter programs. These programs are costing billions of dollars in research and development (R&D) expenditures and hundreds of millions of dollars for each aircraft. Not only are these aircraft expensive, but the personnel to fly and maintain them significantly increase in costs. Even though these weapons systems are very expensive, the U.S. Air Force insists that they are necessary for air superiority. *Since future UCAV requirements are to replace all manned aircraft by the year 2030 is it worth wasting billions of dollars on systems that will be phased out in less than 25-years?* Chapters II and III will be dedicated to answering this question. This chapter will discuss some necessary design modifications to the F-16, and provide a dollar cost comparison of the F-16 UAS vs. the manned F-16 and F-22 projects. Chapter III will show how the F-16 UAS is the best option for Congress and the U.S. Air Force by utilizing of the Nash arbitration game theorem.

B. F-16 UAS

Given BAe's contributions success, one can see that any aircraft within the U.S. inventory can be easily converted into a drone. So, why use the F-16? According to Major William L. Hartzfeld, 510th Fighter Squadron Intelligence Officer for Operation Allied Force; "high risk missions such as surface-to-air missile (SAM) hunting and double-digit SAM (SA10, 20, etc.) suppression is the Air Forces biggest risk area for pilots. The Chief of Staff of the Air Force has clearly said that the F-22 is needed to counter the SAM and 5th generation aircraft threat" (personal communication, July 14, 2006). The F-16 currently handles most of the SAM hunting missions and it will probably continue to bear the load in the future (Bolkom, April 2001). Since the F-16 is already the primary tool for high risk missions like the SAM threat, then why not simply increase its chances success. Additionally, the F-16 is a multi-role fighter. "It performs

all USAF missions such as SEAD [Suppression of Enemy Air Defenses], DCA [Defensive Counterair], OCA [Offensive Counterair], killer scout, deep strike, interdiction, and CAS [Close Air Support]. No other aircraft in the U.S. military can explore the unmanned doctrine in so many areas of combat" (Thompson, 2000). In addition to its flexibility, the F-16 is also the most numerous weapons system available in the U.S. inventory. This large inventory is a key factor in the proper transition from manned to unmanned F-16s. It allows for mishaps during the initial exploration of the concept, proper training, long term investment for the future of the system, and continued flight of manned F-16s during the transition. Given all these benefits, probably the most compelling reason for creating an F-16 UAS is simplicity. During an interview with Mr. Paul Plate, BAe Systems program support services stated; "The F-16 would be very easy to convert since it is a fly by wire system" (Paul Plate, personal communication, January 26, 2006). Since the F-16 is a fly-by-wire system the drone transition does not need any mechanical servos or hydraulic changes. The conversion would only require the installation of an on board computer and some communications modifications. This simplicity would significantly reduce the cost of the F-16 UAS. Converting the F-16 into a drone may be very simple, but the need to ensure survivability is also important. By implementing small but important design modifications the F-16 UAS could easily outperform its current manned counterpart.

C. BASIC DRONE MODIFICATIONS

The basic requirements in converting an F-16 to a UAS revolve around flight controls and communications. Engineers will need to incorporate computer systems that can fully control all aspects of the aircraft. This will allow the aircraft to be completely controlled remotely for flight. Communications equipment is also required for remote-control operation and sensor feedback to the ground operator (Thompson, 2000). "One possible location for engineers to put this datalink hardware is in the vertical fin base originally designed to hold the cancelled USAF airborne self-protection jammer internal electronic warfare system" (Thompson, 2000). Rough estimates from BAe on converting an F-16 into a UAS of this capacity run about $2 million each. However, this type of

drone will only provide the government with a system that is equivalent to the F-16 and the only advantage would be its remote flight.

A few simple modifications would increase the UAS's capabilities significantly. Radar detection is always a great concern and the UAS's radar signature could be decreased by removing the large canopy required to house a pilot and replacing it with a radar absorbing cover. By decreasing the drone's radar signature, its survivability rate increases. In addition, Paul Plate from BAe feels that removal of the ejection seat, and decomposition chamber would significantly decrease the on-board weight significantly (Paul Plate, personal interview, January 26, 2006). This decrease in weight could allow for an increase in range by installing a 2300 pound cockpit fuel tank (Thompson, 2000). This cockpit tank would increase the F-16 UAS's range by approximately 200 nautical miles in combat (Thompson, 2000). One other possible enhancement could be a small camera mounted near the front of the aircraft at a lookup angle so the remote ground operator could remotely re-fuel the aircraft from a tanker (Thompson, 2000). If this enhancement were implemented the cockpit fuel-bladder would be unnecessary, leaving significant weight allowance for more on-board ordinance.

According to BAe experts, removing the hydrazine tank (a 56lb device used as a last ditch effort to safely fly an F-16 with mechanical problems to the ground) would provide the perfect space for an on-board remotely activated self-destruction system (Paul Plate, personal interview, January 26, 2006). A self-destruct system would provide a safety net for a drone that is having mechanical problems and cannot land safely or preventing it from getting into enemy hands if shot down.

Figure 2. Lockheed Martin artist design of an F-16 UAS. (Thompson, 1998)

F-16 product support engineers and BAe experts agree that the F-16 is limited to 9 Gs due to its weak wings (Torres E. Torres, personal interview, November 17, 2005, & Paul Platte, personal interview, January 26, 2006). The F-16 wings have problems with what are called finger braces. There are only four of these braces in the top and four on the bottom of the wings design. This faulty design constantly creates fractures within the wings when the aircraft exceeds its 9-G limit (Paul Platte, personal interview, January 26, 2006). By re-enforcing the F-16 finger braces or re-designing its wings, the F-16 could possibly increase its G-limit by three to six additional Gs. In addition to re-designing the F-16's wings, the utilization of vectored engine thrust would significantly enhance the F-16 UAS's maneuverability. A rough estimate of a drone with these modifications would increase its cost by more than $4 million. This estimate does not consider any research and development (R&D) costs. It also does not consider any operational or maintenance costs. However, R&D costs would be relatively insignificant compared to the $38 billion F-22 R&D funds already spent. F-16 UAS R&D costs may be as low as $20 million or as high as $500 million.

D. A F-16 UAS, F-16, AND F-22 DOLLAR COST COMPARISION

The following comparison is not perfect. It was developed by accessing information from Congressional budgets, and on-line sources. However, to prevent a

bias for UAS technology, this cost comparison always assumes the worst estimates for the F-16 UAS the best estimates for the F-16 and F-22. By doing a cost comparison in this way, it provides a fairer estimation of the costs related to the three systems.

Figure 3. F-16 (Left) and an F-22 (Right)

1. Aircraft Costs

The F-22 is reported to have a unit purchase price of $211.815 million per aircraft (DTIC, 2006, February). This cost has changed throughout the past few years due to Congressional demands for the number of aircraft required for delivery. However, this is the current estimate used within the Department of Defense budget proposal from the 2007 Operational System Development request.

The F-16 costs $18.8 million for the currently used C/D model (Air Combat Command, 2006, June)

As discussed earlier the approximate cost of a drone conversion is $4 million. However, for the benefit of the doubt, I will bump this cost analysis up to $5 million.

2. Aircrew Costs

The F-22 is a single-seat multi-role fighter/attack aircraft. While initially only experienced, highly qualified pilots will be assigned to the aircraft, eventually a steady state will be reached and lower ranking, less experienced pilots will be allowed to fly the

aircraft. Still, the F-22 is highly complex aircraft and it is unlikely that brand new pilots will be allowed to fly the jet. Additionally, to make the best use of their resources, fighter squadrons are typically assigned more pilots than aircraft. This is usually referred to as “crew ratio.” (Riden, 2005, December) The standard crew ratio is 1:1.3 pilots or the number of aircraft assigned to a squadron times 1.3 pilots. (Riden, 2005, December) However, because of the high reliability built into the aircraft, it is estimated that F-22 squadrons will be allotted a 1:2.5 crew ratio. (Riden, 2005, December)

The F-16 is very similar to the F-22 in roles, but its reliability is not as high. As a result, it must use the standard 1:1.3 crew ratio.

While the UAS is unmanned, it still will need pilots to fly it. However, since it is unmanned, training pilots is much less expensive since simulators can be used for most of their training. Additionally, the drone does not require one pilot to fly one aircraft. According to Dr. Dave Netzer at the Naval Postgraduate School, “Multiple UAVs can be flown by a single pilot” (D. Netzer, Lecture, January 2006). This type of capability would allow one pilot to fly dozens of drones to a certain destination. Once in combat, a one-to-one pilot/aircraft ratio may be required. This process will reduce the burden of crew rest and the crew ratio required. Since pilot availability will increase, the crew ratio would decrease. This means an assumption of one pilot would be required to operate three drones, creating a crew ration of 3:1.

The average cost of one fighter pilot is approximately $8.3 million. The following values were used to assume these valuations.

a. Average Time in Military: 8-years (Riden, 2005, December)

b. Average Salary per year: $85,000 (Military Connection, 2005)

c. Approximate Training Costs: $7,000,000

d. Flight Bonus: $220,000

e. Death Insurance: $400,000

Though the total costs for a F-16 UAS would be less due to cuts in training and possibly flight bonus, this thesis will not change aircrew costs.

a. RESULT:

i. F-22 Total Aircrew Cost = $8.3 Million X 2.5 crew ratio = $20.75 Million

ii. F-16 Total Aircrew Cost = $8.3 Million X 1.3 crew ratio = $10.79 Million

iii. F-16 UAS Total Aircrew Cost = $8.3 Million X a 3:1 or (1/3) crew ratio = $2.76 Million

3. Maintenance Costs

Most flying squadrons have an associated maintenance unit. This is not part of the flying squadron, but is responsible for the aircraft. Because this thesis is not constrained to buying whole squadrons of aircraft, we will attempt to determine the number of maintainers required per aircraft. Because aircraft maintenance troops do vary an average salary will be applied. Additionally, a $1 Million dollar annual equipment cost per aircraft will be applied.

b. Current F-16 fighter maintenance units have about 8.6 maintainers per aircraft (Riden, 2005, December). However, the F-22 is reported to require only about half this number. This would produce a figure of 4.3 maintainers per aircraft (Riden, 2005, December). The drone maintenance average is very difficult to arrive at. After a detailed discussion with BAe engineers and maintainers no real ratio could be derived. Nevertheless, we know there is no requirement for a life support maintenance crew since the drone is unmanned. These risk-of-life inspections include egress and life support equipment that are the most stringent of all the required inspections (Paul Platte, personal interview, January 26, 2006). Since these inspections would be deleted, the complete egress back shop could be cut out. Additionally, BAe experts agreed that the number of maintainers required for routine maintenance and flight preparation could easily be cut in half. This is because the F-16 UAS will only fly for tests and combat, and won't be needed for continual flight training. This does not mean that the F-16 UAS will not need routine inspections. Even though it may not fly as often as a manned F-16, it will still need preventive maintenance checks. In addition, according to Colonel Brian H. Greenshields, Naval Postgraduate School Special Operations Command Chairman,

"current unmanned weapons systems are required to fly at least every 72 hours for air worthiness checks" (Brian H. Greenshields, personal interview, July 5, 2006). Even though the number of maintainers required for an F-16 UAS may be fewer than for the F-22, for the purposes of this thesis the same ratio as the F-22 will be employed.

c. The average cost of one maintainer is $520,000 each. The following values were used to arrive at this figure:

i. Average Time in the Military: 4 years (Riden, 2005, December)

ii. Average Salary per year: $22,500 (Military Connection, 2005)

iii. Approximate Training Costs: $30,000

iv. Bonus: N/A

v. Death Insurance: $400,000

d. RESULT:

i. F-22 Total Maintenance Cost = $520,000 X 4.3 maintainers + $1 Million= $3.24 Million

ii. F-16 Total Maintenance Cost = $520,000 X 8.6 maintainers + $1 Million= $5.72 Million

iii. F-16 UAS Total Maintenance Cost = $520,000 X 4.3 + $1 Million= $3.24 Million

4. Summary of Results

By taking the calculations and assumptions of all the items discussed in the paragraphs above Table 2 below was created. As one can see the dollar costs differing considerably. The F-22 can be considered more expensive while the F-16 and F-16 UAS seem significantly less expensive. However, dollar costs alone can be deceiving. In the next chapter, the Nash Arbitration model will be used. This model, with the aid of some technical considerations not within this dollar cost comparison, will illustrate why the F-22 is more cost effective than the F-16. However, this argument does not hold water when comparing the F-22 to the F-16 UAS.

Per Aircraft	**F-16**	**F-22**	**F-16 UAS**
Aircraft Cost	18,800,000	211,000,000	5,000,000
Aircrew Cost	10,790,000	20,750,000	2,760,000
Maintenance Cost	5,720,000	3,240,000	3,240,000
Total Cost Each Aircraft	**35,310,000**	**234,990,000**	**11,000,000**

Table 2. Results of F-16, F-22, F-16 UAS cost comparison

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III. THE NASH ARBITRATION MODEL

A. WHAT IS THE NASH ARBITRATION MODEL?

The Nash Arbitration Model was designed by mathematician, John Forbes Nash, Jr. It is a theory he developed in 1949, which showed that competitive behavior among decision-makers leads to a non-optimal equilibrium. This was a radical idea which challenged the classical economic theory of Adam Smith that free competition leads to the best results and the Darwinian Theory that natural selection leads to improvement of the species. His non-optimal arbitration theory is the reason why systems like the F-22 are approved by Congress. It is a process that simulates two groups of people with diametrically opposed interests and provides a solution that is in some sense fair and acceptable to both groups. By utilizing the Nash arbitration model one can prove that the obvious choice may or may not always be the best choice. The model is now widely used throughout the world to settle arguments through negotiations. This chapter will utilize the Nash Arbitration model to compare the F-16 versus the F-22 and the F-22 versus the F-16 UAS. By going through this exercise, one will understand why the F-22 is a valid and acceptable to Congress but it should also show how the F-22 argument is inferior when compared to the F-16 UAS.

B. ARGUMENT ONE: THE F-16 VERSUS THE F-22

1. Players

Air Force air superiority versus Congressional budget cuts

2. Concern

What should the Air Force develop to minimize budget costs and maintain air superiority until the UCAV fleet is available in 2030? Should the Air Force develop manned F-16s (Multi-role fighter aircraft) or develop the F-22?

3. Assumptions

For the purposes of this thesis let's assume that Congress wants to decrease budget spending in this area of concern to $1.5 billion per year until the UCAV fleet is ready. This will provide a total budget of $37.5 billion.

This analysis will be based on the aircraft purchase price, aircrew costs, and maintenance personnel costs provided in Chapter II. Additionally, it will consider two other factors not discussed in Chapter II: kill ratio, and service of life.

i. The Aircraft kill ratio and service of life are important factors when considering an aircrafts value. Kill ratio is the aircrafts ability to survive in combat. If an F-16 fought an F-16 the kill ratio would be 1:1 since they would be similar weapons systems. However, if an F-16 were to fight an F-22 the results would be very different. Considering this ratio can change the option to purchase considerably. For example, the kill ratio for the F-22 vs. the Russian-built SU-35 is considered to be a 1:10 ratio (Chairforce, 2006). This means that one would have to buy 10 SU-35 aircraft before they would be equivalent threat to a single F-22. The best way to determine a kill ratio is to create a standard. Let's say the F-16 is the primary platform. This means that the F-16 will have a value of one and it will have a kill ratio of 1:1. The SU-35 is reported to have a 1:10 ratio and the F-16 is reported to have a 1.5:1 ratio against the SU-35 (Chairforce, 2006). By using these two calculations, an F-16 to F-22 kill ratio of 15:1 can be extrapolated.

ii. Service of Life (SoL) is another important consideration. This is the expected number of flight hours an aircraft can fly before it needs to be retired. The F-22 is estimated to have a 9000 flight hour SoL (FAS, 2000, April). The F-16 is known to have a 6000 flight hour SoL (FAA, 2005, December). If the USAF flies these aircraft approximately 10 hours a week, an assumption of

520 flight hours per year can be made. If these aircraft are flying 520 hours per year, then the F-22 has a SoL of 17.3 years (9000/520) and the F-16 has a SoL of 11.5 years (6000/520).

A 10% loss of aircraft and aircrew also needs to be factored in due to crashes and combat.

This thesis will assume that Congress and the USAF would like to replace 75% of the entire F-16, and 100% of its aging F-15 inventries over the next 25 years. Since the F-15 is the USAFs current Air Superiority aircraft and there is no real kill ratio for the F-15 we will assume that the F-15 has a 1:3 kill ratio. Since there are 738 F-16s and 396 F-15s in the Active Duty USAF fleet, the government requirement would replace an equivalent of 1742 F-16s ((396 F-15 x 3 Kill ratio) + (75% x 738)). If an equivalent number of 1742 F-16s is unattainable given a $37.5 billion cap then the closest solution to that cap would be best. If this solution is obtainable, then the least expensive solution would be best.

Figure 8 describes the results. It provides values that can be utilized to find the perfect F-16 and F-22 mix. The Total Value of Each Aircraft is the Total Cost of Each Aircraft times 25 years divided by Service of Life multiplied by Loss of system/life then divided by the kill ratio. This number provides the value of each aircraft to sustain the equivalent airpower of one F-16 for 25 years.

Per Aircraft	**F-22**	**F-16**
Aircraft Cost	211,000,000	18,800,000
Aircrew Cost	20,750,000	10,790,000
Maintenance Cost	3,240,000	5,720,000
Total Cost Each Aircraft	**234,990,000**	**35,310,000**
Kill Ratio	15:1	1:1
Service of Life	17.3 yrs	11.5 yrs
Loss of system/life	10%	10%
Total Value of Each Aircraft	**24,097,974**	**62,545,522**
25 year goal equivalent to F-16s	1742	1742
$ Cap	37,500,000,000	37,500,000,000

Table 3. Costs/Value and Assumptions for Optimal Efficiency Calculation USAF vs. Congress, F/A-22/F16

4. Options

On a scale of 1-to-4, with 4 being the best and 1 being the worst option, this argument assumes the rankings below for both parties:

a. The U.S. Air Force

In this project we assume the primary concern for the Air Force is Air Superiority. Air Superiority is its primary concern because the mission of the U.S. Air Force is to defend the United States and protect its interests through air and space power. To achieve that mission, the Air Force has a vision of *Global Vigilance, Reach, and Power* (USAF, 2000). That vision orbits around three core competencies: Developing Airmen, Technology-to-Warfighting, and Integrating Operations (USAF, 2000). These core competencies yield six distinctive capabilities. One such capability is Air and Space Superiority (USAF, 2000). The Air Force feels that with Air Superiority it can dominate enemy operations in all dimensions -- land, sea, air, and space (USAF, 2000). Since Air Superiority is the top priority, the F-22 holds the most utility (Score of 4). The second highest payoff (Score of 3) would be a mix of F-22s and F-16s. The F-16 is an aging platform that American adversaries have or will have the capability to outperform or destroy within the next few years. Even though the F-16 is aging, the Air Force would rather have a mixture of weapon systems than nothing at all. The third highest payoff (Score of 2) would be to buy only F-16s. If the USAF has to abandon the F-22 at least it can have new F-16s to replace the aging fleet. Lastly, the lowest payoff (Score of 1) would be no new aircraft until the UCAV fleet can replace the existing inventory. This would become a logistical nightmare for the Air Force and increase maintenance costs significantly.

b. Congress

Congress understands that Air Superiority is key to possessing to the most powerful military in the world. However from its perspective, there are many other factors that must be considered: 1) Budget costs must be reduced to cut the deficit 2) The risk of losing our soldiers in combat must be prevented 3) It is critical to the needs of the American people as a whole and 4) The UCAV fleet will be on line in 2030 and all active manned aircraft will be replaced. By taking these factors into consideration Congress is likely to prefer a mixture of F-16s and F-22s. This is their highest payoff (Score of 4).

The F-22 is the future and would be a great, it is an expensive weapon system compared to the F-16 and F-16s can be easily modified to integrate future technologies. Additionally, multiple companies will be in business producing both systems, thereby decreasing the unemployment rate. This makes a mix of F-22s and F-16s the best solution.

Since the F-16 is so versatile Congress chooses the F-16 as its second highest payoff (Score of 3). The average fighter pilot of 8-years is valued at approximately $8.3 million dollars. This is after considering training, flight bonus, death insurance, and annual pay. The risk of losing a life is an awful decision to make, but a necessary one. Since the cost of a new F-16 is so much less then an F-22 and the UCAV will replace the current fleet within 25 years the risk of life is not as important. The next highest payoff (Score of 2) is to develop nothing. Maintenance costs do tend to increase substantially over time, but the cost of maintaining an old aircraft fleet vs. the costs for an F-22 fleet would be less over 25 years. Finally, the least payoff (Score of 1) is to develop all F-22s. This would be a multi-billion dollar investment for only a 25-year period. Congress is projected to feel this is not a good solution.

5. Nash Arbitration Grid

It is truly difficult to determine the actual utility of each of these rankings for the Air Force and Congress without directly talking to decision makers themselves. Therefore, this thesis assumes that the ordinal utility of these rankings equals the cardinal utility; that is four is two times as good as two and so forth. Making this assumption is necessary in order to apply the Nash Arbitration. With this in mind, the Nash Arbitration two-person game produces the following results: (See Figure 4)

The two-person game shows that both the USAF and Congress have a dominate strategy. The USAF wants to choose the row “buy F-22s”. This row will allow it to purchase the F-22 in full or partially. Congress, on the other hand, has the dominate strategy to choose the column “buy F-16s”. This column prevents them from fully purchasing the F-22. As a result, the Nash point will be (3, 4).

	Congress	
	Buy F-16	Don't Buy F-16
Buy F-22	3, 4	4, 1
USAF		
Don't Buy F-22	2, 3	1, 2

Figure 4. Arbitration grid USAF vs. Congress, F-22 and F16

By choosing the (3, 4) point the USAF will not get all F-22s but only a mix of both aircraft. This is not its optimal choice, but it is better than nothing. Congress is very happy with the results. It can buy both aircraft, keeping budget costs down, risking less life since the F-22 is a more advanced weapons system, and keeping the American people happy since there will be more jobs. When these assumptions are graphed, the following picture results (See Figure 5).

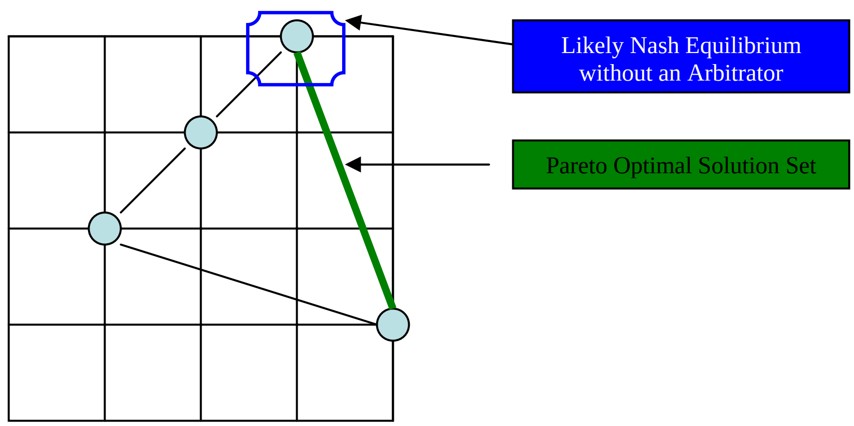

Figure 5. Nash Equilibrium USAF vs. Congress, F-22/F16

6. Strategic Moves

The graph in Figure 4 shows that the outcome is (3,4). Point (3,4) is to purchase a mix of F-22s and F-16 aircraft. However, as the information is reviewed, the (3,4) point is not the optimal point for both sides. This is due to the fact that the Air Force is not getting what it wants most. The optimal solution does exist, but it lies within the Pareto

Optimal Solution set line. Before the USAF opts to bargain with Congress it decides to see if there are any strategic moves that can be exercised. A strategic move is something that can force the opposition to choose a less optimal option. There are three types of strategic moves within an arbitration model. These moves are the first move, the threat, and the promise. What strategic moves are available to the USAF within Figure 5?

a. Is there a FIRST MOVE for the USAF during this argument? A first move provides the ability to act on a decision first. It is something that must be considered, since it may help increase one's chance of obtaining the best solution. For example: a parent has two ice cream cones, one with chocolate ice cream, the other with coffee. His two children dislike coffee ice cream and instead both desire the chocolate. The child who moves first will get to pick the option he wants, leaving the other child with what is left over. By looking at the USAF's options for a first move, we can see how this would give it an advantage over Congress.

i. If the USAF's optimal solution is to buy F-22s and Congress' is to buy F-16s the result would be block (3,4)

ii. If the USAF tries to be deceptive and chooses the 'Don't Buy F-22s' row, Congress would choose the 'Buy F-16s' Column. This would result in block (2, 3). This block would put the USAF in a worse position than option A. RESULT: Since the USAF is unable to better its position by taking the first initiative it does not have a first move.

b. Can the USAF wield a THREAT? A threat is something that forces the opposition to choose something other than its optimal solution. For example, a family wants to go out to the movies to see a film for which they have been waiting months. However, the parents also want their children to eat all their vegetables during dinner. The children hate eating their vegetables. The parents choose to coerce the children into eating their vegetables by telling them that unless the do so, they will spend their time at home in bed and not go to the movies. The parents know that this threat would also ruin their night out. By utilizing this threat, the children are forced to choose to eat the vegetables and enjoy the movie or go to bed. Neither choice is optimal, but one is much

better than the other. By looking at the USAF's options regarding a threat, one can see whether it can force Congress to make a decision that will favor the USAF.

i. USAF wants Congress to pick the 'Don't Buy F-16s' row in Figure 6. So, if the USAF threatened Congress to select the 'Don't Buy F-16s' block by picking another option would it better its position? The answer is NO. The only other option for the USAF would be to select the 'Don't Buy F-22s' block if Congress didn't choose the 'Don't Buy F-16's' block. This option would actually favor Congress. RESULT: The USAF does not have a THREAT.

c. Does the USAF have a PROMISE? A promise is an agreement that allows both sides to work together for an acceptable solution. For example, a teenager wants his parents to buy him a new car. The parents can't afford to buy him one but are willing to let him use their Yugo. The teen does not want to be a laughing stock at school by being seen in a Yugo, so he makes a promise to get a job and pay for the car on his own if his parents will sign the loan papers. This promise is not optimal for either side, but it does allow their teenager to get a new car even though it means he'll have to get a job.

i. USAF wants Congress to pick the 'Don't Buy F-16s' block in Figure 6. So, If Congress takes 'Don't Buy F-16s' then the USAF will promise to take 'Don't Buy F-22s'. RESULT: The USAF does not have a PROMISE because it will not get its optimal solution.

The USAF's final conclusion is that it has no strategic moves to better its situation. As for Congress, there is really no need to look for a strategic move. It is already getting its best choice and knows that the USAF has no strategic moves. The best solution is unquestionably a mix of F-22s and F-16s. An analysis of the two is necessary to see what the best mix should be. This is done by taking the estimated values of both aircraft to minimize cost but increase efficiency.

7. The Optimal Mix

The optimal mix can be discovered by using two separate techniques. One technique is to find the Minimal Annual Cost to obtain the 1742 F-16 replacement requirement. This calculation would be subject to: X = # of F-22s; Y = # of F-16s, 15X + Y >= 1742. The X value for F-22s would be 15 times the value of Y since there is a 15:1 kill ratio. The second technique is to find the maximum mixture of aircraft subject to an annual cost. This calculation would be: X= # of F-22s, Y= # of F-16s, Max 15X + Y is Subject to Annual Cost <= Annual Budget. Both equations would utilize the following calculation to discover the Annual Cost of both the F-22 and F-16:

[((1.1) 25/17.3 (211,000,000) + (1.1 x 20,750,000) + 3,240,000)/15] + [(1.1) 25/11.5 (18,800,000) + (1.1 X 10,790,000) + 5,720,000)]/25

Using an application in Microsoft Excel called Excel Solver one can easily determine the optimal mix equation. As shown below in Table 4, utilizing both the minimal annual cost to maximize efficiency the USAF would be very happy with the results. Even though the best decision is to develop a mix of both F-22s and F-16s, the 15:1 kill ratio theoretically forces Congress to buy all F-22's. However, even though the best result is to buy 103 F-22s over the next 25 years there is no possible way to obtain the 1742 efficiency goal with the total budget cap. The maximum efficiency rate capable is only a 1545 F-16 equivalent. This Nash Arbitration argument is one of the reasons why the F-22 is such a powerful lobbying tool in Congress. Its efficiency rate is able to defend its high cost.

x	y	EFFICIENCY	Cost	Total Budget
103	0	1545	$37,231,371,300.58	$37,500,000,000
		GOAL		
		1742	Annual Cost	
			$1,489,254,852.02	

Table 4. Minimal Annual Cost/Max Efficiency for F-22/F-16 Solution

C. ARGUMENT TWO: THE F-22 VERSUS THE F-16 UAS

1. Players

Air Force air superiority versus Congressional budget cuts

2. Concerns

What should the Air Force develop to minimize budget costs and maintain air superiority until the UCAV fleet is available in 2030? Should it develop the F-22 or the F-16 UAS?

3. Assumptions:

a. As with the previous argument, the F-16 versus the F-22, this analysis will be based on the aircraft purchase price, aircrew costs, and maintenance personnel costs provided in Chapter II.

b. Additionally, the kill ratio and Service of Life for the F-22 will be the same as in the previous argument. The drone is an unknown. However, after long discussions with engineers, if the $5 million version of the drone was developed, a safe F-16 to F-16 UAS kill ratio may be 4:1. However, for purposes of this thesis a 2:1 F-16 to F-16 UAS kill ratio will be used.

Even though engineers have stated that the Service of Life (SoL) for the F-16 UAS would be the same as the F-16 there is difficulty in believing this. The F-16 UAS is a system that would be developed from old airframes. So instead of giving the F-16 UAS a complete 6000hrs SoL this thesis will only assume a 4500hr SoL for the F-16 UAS. That is 25% less than a new F-16. However, another consideration is that the F-16 UAS will be flown significantly less than the F-16. This is due to a reduction in pilot training. Since pilots do not need to fly the actual aircraft to maintain their required flight hours the F-16 UAS requires less flight time per year. Since the F-16 UAS will be flown less than the F-16 annually the actual years in service changes. An assumption that the F-16 UAS will only fly 4-hours per week will be considered. This makes an annual flight requirement of 208 hours. As a result the F-16 UAS SoL is 21.6 years (4500/208).

c. We should assume a 10% loss of aircraft is a factor due to crashes and combat. However there will not be a 10% loss of aircrew since there are no pilots in the UAS.

4. Options:

On a scale of 1-to-4, with 4 being the best option and 1 being the worst option, this thesis assumes the rankings below for both parties.

a. The U.S. Air Force

Once again, Air Superiority is a top priority for the USAF. Even though the F-22 has a better kill ratio the F-16 UAS has the unique capability of being unmanned. This allows the USAF to insert combat aircraft into hostile high risk areas without worrying about Loss of life or loss of high value equipment. This would lead the Air Force to seek a mix of F-22s & F-16 UASs having the highest utility (score of 4). The second highest payoff (score of 3) would be to purchase only F-22s. The F-16 UAS is a very unique piece of equipment but it is far less advanced then the F-22. The third highest payoff (score of 2) would be to buy only F-16 UAS. If the USAF had to abandon the F-22 at least it can have a F-16 UAS fleet to replace the current one. Lastly, the lowest payoff (score of 1) would be no new aircraft until the UCAV fleet can replace the existing inventory.

b. Congress

Congress would likely feel that the F-16 UAS represents the perfect solution its budget cut, its concern over loss of life, and its need to meet the needs of the American people as a whole, the UCAV fleet is on line in 2030. This gives the F-16 UAS the highest payoff of a (4). A mix of F-22s and F-16 UAS earns the next highest payoff of a (3). A payoff of (2) is to develop nothing. Maintenance costs do tend to increase substantially over time but the cost to maintain an old aircraft vs. the costs for a new F-22 fleet are minimal for a 25-year period. Finally, the least payoff (1) is to develop all F-22s. This would be a multi-billion dollar investment for only a 25-year period. Congress feels this is not a good solution.

5. Nash Arbitration Grid

As in the previous example, it is truly difficult to determine the actual utility of each of these rankings for the Air Force and Congress without directly asking the decision makers. Therefore, this thesis assumes that the ordinal utility of these rankings equals the cardinal utility; that is, four is two times as good as two and so forth. Making this assumption is necessary in order to illustrate the Nash Arbitration. With this in mind, the following Nash Arbitration two person game results (See Figure 6):

The two-person game shows that both the USAF and Congress still have a dominate strategy. The USAF wants to choose the row 'Buy F-22s'. This row will allow it to purchase the F-22 in full or partially. Congress, on the other hand, has the dominate strategy to choose the 'Buy F-16 UAS' column. As the result, the Nash point without an arbitrator will be (4, 3). This answer has reversed from the F-16/F-22 comparison. By introducing the F-16 UAS, the USAF gets its top choice and Congress gets its second best choice.

<u>USAF vs. Congress Game:</u>

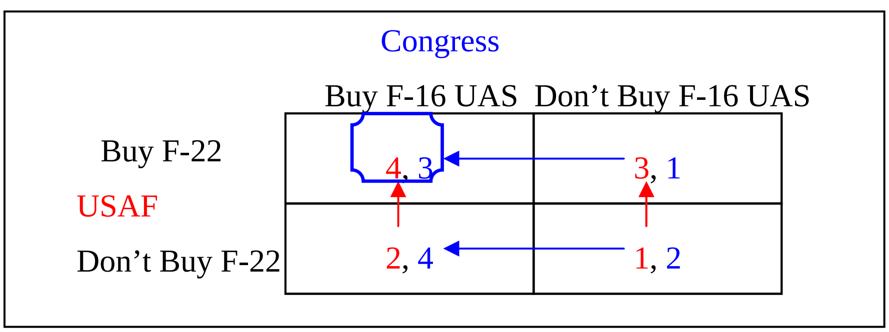

Figure 6. Arbitration Grid USAF vs. Congress, F-22 and F-16 UAS

When these results are graphed, the following picture results (See figure 7).

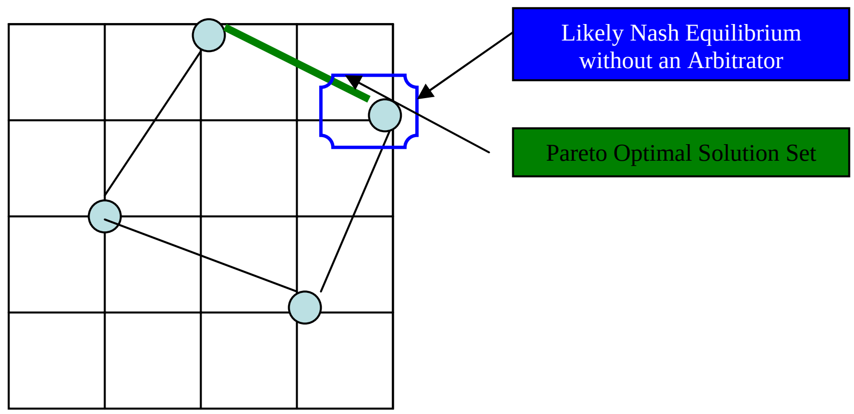

Figure 7. Nash Equilibrium USAF vs. Congress, F-22 and F-16 UAS

5. Strategic Moves

The graph in Figure 6 shows that USAF and Congress would choose the Nash equilibrium of (4,3). Point (4,3) is to purchase a mix of F-22s and F-16 UAS aircraft. Even though the result to have a mix of F-22s and F-16 UAS is the same as in the previous calculation, the graph is quite different. By introducing the F-16 UAS we not only have a Nash Equilibrium, it is also the Pareto Optimal solution. Since the Nash Equilibrium and Pareto Optimal solution are equivalent, there is no need to search for a Strategic Move.

6. Optimal Mix

Since the best solution is a mix of F-22s and F-16 UASs, an analysis of the two is necessary to see what the best mix should be. This is done by taking the estimated values of both aircraft to minimize cost, but increase efficiency. For this calculation, information discussed in the assumptions section of this argument will be considered. Figure 3 is the result of listing the six F-22 and F-16 UAS considerations. It provides values that can be utilized to find the perfect F-22 and F-16 UAS mix.

Per Aircraft	**F-22**	**F-16 UAS**
Aircraft Cost	211,000,000	5,000,000
Aircrew Cost	20,750,000	2,760,000
Maintenance Cost	3,240,000	3,240,000
Total Cost Each Aircraft	**234,990,000**	**11,000,000**
Aircraft Efficiency	15:1	2:1
Service of Life	17.3 yrs	21.6 yrs
Loss of system/life	10%	10% not on life
Total Value of Each Aircraft	**24,097,975**	**10,197,870**
25 year goal equivalent to F-16s	1742	1742
$ Cap	37,500,000,000	37,500,000,000

Table 5. Costs/Value and Assumptions for Optimal Efficiency Calculation USAF vs. Congress, F-22/ F-16 UASs

Once again we will discover the optimal mix by utilizing the Minimal Annual Cost to obtain the 1742 F-16 replacement requirement. This calculation would be subject to: X = # of F-22s, Y = # of F-16 UASs, 15X + 2Y >= 1742. The second technique is to find the maximum mix of aircraft subject to an annual cost. This calculation would be: X= # of F-22s, Y= # of F-16 UASs, Max 15X + 2Y is Subject to Annual Cost <= Annual Budget. Both equations would utilize the following calculation to discover the Annual Cost of both the F-22 and F-16 UASs:

[((1.1) 25/17.3 (211,000,000) + (1.1 x 20,750,000) + 3,240,000)/15] + [((1.1) 25/21.6 (5,000,000) + 10,790,000 + 3,240,000))/2]/25

Using the Excel Solver application for both optimal mix equations the answer can be easily determined. As shown below in Figure 9, utilizing both the minimal annual cost to maximize efficiency there is a significant difference in results. Instead of developing only F-22s, the equation requires the development of only F-16 UASs. Additionally, the F-16 UAS allows the USAF and Congress to reach the optimal efficiency goal and cut the total budget by 71%. That is a savings of $26.73 billion. This reduces the annual costs from the approved $1.5 billion to $430.83 million.

x	y	EFFICENCY	Cost	Total Budget
0	871	1742	$10,770,560,185.19	$37,500,000,000
		GOAL		
		1742	Annual Cost	
			$430,822,407.41	

Table 6. Minimal annual Cost/Max Efficiency for F-22/F-16 UAS Solution

D. SUMMARY

Using the Nash Arbitration model with an optimal efficiency calculation, one is able to prove that the F-16 UAS can significantly enhance the USAF's capabilities for the 25-year transition period. It allows the USAF to reach its efficiency goals, significantly reduce total budget costs, and reduce the risk-of-life factor to zero. As a result, the F-16 UAS is the choice solution for a smooth, effective, and inexpensive transition.

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IV. KOSOVO/OPERATION ALLIED FORCE (OAF)

A. INTRODUCTION

According to Martin Libicki: “For the United States and its allies, people are expensive; stuff is cheap. Silicon is getting cheaper, and casualties are growing prohibitively expensive. Thus, as any economist would argue, it makes sense to substitute what is getting cheaper for what is getting more expensive—that is to substitute as much silicon for casualties as one can” (Libicki & Shapiro, 2003). The U.S./NATO campaign in Kosovo was the perfect operation to underscore Martin Libicki’s statement. NATO depleted over 99% of its precision weapons and developed limitations on engagement to protect its personnel from getting killed. These limitations eroded NATO forces’ effectiveness. By utilizing deception techniques, the Federal Republic of Yugoslavia (FRY) was able to avoid NATO attacks, force NATO to waste billions of dollars, and embarrass both military and political leaders. This chapter will discuss the Kosovo/OAF campaign, the FRY’s deception techniques, and how the F-16 UAS aircraft could have been utilized to thwart deception, maintain NATO goals, and save money.

B. BOSNIA/OAF SITUATION

In December 1990, Slobodan Milosevic was elected to be the first President of the Federal Republic of Yugoslavia. Subsequent to his rise in power, he undercut Kosovo’s autonomy and implemented severely repressive policies that excluded Kosovar Albanians from virtually all positions of responsibility, even though ethnic Albanians made up 90 percent of Kosovo’s population (U.S. DoD, 2000). These actions led to a pattern of increased instability in the Balkan region (U.S. DoD, 2000). Yugoslavia and the Balkans as a whole immersed in a series of increasingly violent armed confrontations. Between 1991 and 1992, Slovenia, Croatia, and Bosnia/Herzegovina forcibly seceded from Yugoslavia, while Macedonia did so peacefully. The break-up of Yugoslavia was endorsed by a number of international powers that recognized the right of self-determination of all nations except the Serbs who wanted to continue living in greater Yugoslavia. Milosevic did not agree with the separation and between 1992 and 1995, he

instigated wars in Slovena, Croatia, and Bosnia. These wars led to NATO involvement. In 1998, Serbia incited systematic ethnic violence against the Kosovar Albanians, precipitating a crisis that compelled the international community and NATO to act on the diplomatic and military fronts (U.S. DoD, 2000). Even though the Serbian leader agreed to refrain from attacks, violence in Kosovo quickly resumed. "While blocking international diplomatic efforts, Milosevic was finalizing a barbaric plan for expelling or forcing the total submission of the Kosovar Albanian community" (U.S. DoD, 2000). On March 20, 1996, the day after peace talks were officially suspended, Serbian forces launched a major offensive and began driving hundreds of thousands of ethnic Albanians out of their homes and villages, summarily executing some of them, and setting fire to their houses (U.S. DoD, 2000). These acts of violence forced the United States and its NATO allies to turn from a path of diplomacy to the use of force. The military campaign was dubbed as Operation Allied Force (OAF) led by the Supreme Allied Commander Europe, General Wesley Clark.

NATO and the United States expressed three primary interests during the crisis. First was to stop Serbian aggression in Kosovo. This aggression directly threatened peace throughout the Balkans and the stability of southeastern Europe. The second was to halt repression in Kosovo. This repression created a humanitarian crisis of staggering proportions. The third and final interest was to reverse Milosevic's challenge to the credibility of the NATO alliance.

In response to these primary interests the United States and NATO set specific strategic objectives for their use of force in OAF. According to a 2000 report to Congress, these objectives were to:

- "Demonstrate the seriousness of NATO's opposition to Belgrade's aggression in the Balkans" (U.S. DoD, 2000).
- "Deter Milosevic from continuing and escalating his attacks on helpless civilians and create conditions to reverse his ethnic cleansing" (U.S. DoD, 2000).
- "Damage Serbia's capacity to wage war against Kosovo in the future or spread the war to neighbors by diminishing or degrading its ability to conduct military operations" (U.S. DoD, 2000).

These objectives were to be met in five phases under NATO's operational plans.

- Phase 0 was the deployment of air assets into the European theater (U.S. DoD, 2000).

- Phase 1 would establish air superiority over Kosovo (creating a no-fly zone south of 44 degrees north latitude) and degrade command and control and the integrated air-defense system over the whole of the Federal Republic of Yugoslavia (U.S. DoD, 2000).

- Phase 2 would attack military targets in Kosovo and those Yugoslav forces south of 44 degrees north latitude, which were providing reinforcement to Serbian forces in Kosovo. This was to allow targeting of forces not only in Kosovo, but also in the Federal Republic of Yugoslavia south of Belgrade (U.S. DoD, 2000).

- Phase 3 would expand air operations against a wide range of high-value targets throughout the Federal Republic of Yugoslavia (U.S. DoD, 2000).

- Phase 4 would redeploy forces as required (U.S. DoD, 2000).

The Congressional after report action on the conflict shows that the primary objectives for OAF were to be accomplished through air operations only. These operations relied predominantly on cruise missiles and restricted manned aircraft bombings. Since OAF was limited to using air assets under strict rules of engagement, the campaign proved to be very challenging.

C. THE CAMPAIGN

The OAF campaign was not the simple desert scenario that the U.S. military and some of the NATO nations were used to. In Operation Desert Storm, acquiring targets of interests in the middle of the desert was relatively straightforward. Once a target was acquired, Saddam Hussein did not have the ability to hide his assets unless he buried them under the sand. Even though he could bury his assets, it was not something that could be done, quickly, and if done it would prevent the use of the assets when needed. In contrast, Yugoslavia presented environmental obstacles which aided in the creation of limitations to air attacks and the development of a powerful deception campaign for the FRY. The environment was key to the results.

1. Environment

Since the end of the Cold War in 1991 the United States had dramatically decreased its overseas basing of military forces. Consequently, the success of OAF hinged on the combat capability of deployed forces in areas far from the OAF area of concern. In an interview with Major TJ Hamrick, the Chief of Intelligence weapons and tactics and Deputy Chief of Coalition mission planning cell for OAF, he felt that this distance significantly hampered the effectiveness of the combat pilots. He stated that; "It took so long to fly from Germany and Italy to Kosovo that the pilots had no time to accurately debrief their missions because of crew rest limitations" (T.J. Hamrick, personal interview, December 12, 2005). Not only were the pilots tired from the length of the flight, they were fatigued from continual flights day after day.

The terrain and weather in the Balkans were also a challenge. The Balkans are a rugged mountainous region covered in forests. "The rough, mountainous terrain was ideal for hiding or disguising military activity, as opposed to the desert terrain experienced in Iraq" (Johnson & Meyeraan, 2003) Additionally, the air operations during OAF were hampered by bad weather a significant portion of the time (U.S. DoD, 2000). Cloud cover was greater than 50 percent more than 70 percent of the period of operations (U.S. DoD, 2000). The rough terrain and adverse weather affected target acquisition and identification, increased risk to aircrews, complicated collateral damage concerns, and allowed unimpeded air strikes only on 24 of the 78 campaign days (U.S. DoD, 2000).

The final key to the OAF environment was the Serbian air defenses. The Serbian arsenal was antiquated but plentiful. The systems ranged from antiaircraft artillery and man-portable air defense systems to Surface-to-Air missiles (SAMs). These technologies except for the SAMs, were systems developed in the 1950's through the 1980's that could not reach above 15,000 feet (Thomas, 2000). Even though these systems were antiquated, the terrain and weather made it difficult for American and NATO forces to accurately account for them. Since it was difficult to account for the entire Serbian air defense system it became a significant threat to air assets 24 hours a day 7 days a week. Certain Serbian SAMs were capable of reaching altitudes above 15,000', but did not tend to challenge NATO aircraft because they would have been quickly destroyed.

2. Limitations

As Libicki's statement at the beginning of this chapter reminds us. "People are expensive," and General Wesley Clark was not going to risk his people being harmed. According to Major TJ Hamrick; "General Clark felt the OAF conflict was not worth risking any of his pilots" (T.J. Hamrick, personal interview, December 12, 2005). Since General Clark did not want to put his pilots in harms way, his objective was to utilize cruise missiles as much as possible. In addition, Major Hartzfeld 510th Fighter Squadron Intelligence Officer during OAF, stated that; "all combat missions were not allowed to go below the 15,000 foot deck" (William L. Hartzfeld, personal interview, December 12, 2005). Other than their SAM systems the Serbian defense forces did not have any other anti-air weapons system that could reach above the 15,000 foot deck.

The 15,000 foot restriction was not the only limitation American and NATO forces were required to abide by. Pilots were also only allowed to fire upon a target once they had visually identified it in order to limit collateral damage (Thomas, 2000). Another restriction was a politically imposed rule of engagement (ROE) that aircraft were not allowed to land with unexpended ordinance on board (Thomas, 2000). Landing with unexploded ordinance on an aircraft provides undue risks to the aircraft and its pilot. However, since the Balkans had poor weather and the pilots were fatigued it was difficult to properly identify targets. This forced NATO pilots to drop millions of dollars worth of ordinance in the Adriatic Sea (Thomas, 2000).

3. Deception

To prevent extensive loss in valuable assets and to protect their defensive posture, Serbian forces employed camouflage, concealment, and deception tactics extensively. "The deception operations appeared to focus on reducing Allied success in the air campaign, protecting limited Serbian air and ground equipment, humiliating NATO, and affecting world opinion" (Johnson & Meyeraan, 2003). Even though the Serbs were unsuccessful in preventing NATO forces from destroying many of their key fixed installations such as television and radio stations, petroleum and oil facilities; their efforts enhanced the survival of Serb forces and the majority of their combat power (U.S. DoD, 2000).

With a little intelligence, a clear understanding of the physical and political environment, and ingenuity, the FRY was able to employ an inexpensive deception plan that avoided extensive damage and created a political nightmare for NATO. Its first step towards success was knowing when reconnaissance flights would be conducted, or when satellites flew overhead (Thomas, 2000). This information allowed the FRY to preposition its valued assets and allow them to be to be picked up as targets. Once the reconnaissance missions were complete, the Serbs would hide the actual targets. "They used natural cover such as woods, tunnels and caves, civilian homes, barns, schools, factories, monasteries, and other large buildings to hide their personnel and weapons" (U.S. DoD, 2000). This exchange process usually took place under the cover of night. Their decoy techniques were archaic. The decoys consisted of fake artillery pieces made of long telephone poles painted black with old truck wheels, fake bridges along the Drina River, antiaircraft missile launchers constructed of old milk cartons, and wooden mock-ups of MIG-29 aircraft (Johnson & Meyeraan, 2003) (See Figures 1 & 2) These types of decoys were used to replace most mobile tactical targets and some fixed ones.

Figure 8. Serbian Artillery Decoy

Figure 9. Serbian Surface-to-Air Missile Launcher Decoy

Since this war was only an air campaign, the lack of NATO ground forces and an over reliance on overhead reconnaissance made the implementation of cheap decoys such as seen in Figures 1 and 2 extremely effective. NATO forces would utilize their reconnaissance information to create new targets. These targets were then placed on an air tasking order that prioritized them for destruction. This listing would be used to assign the targets to aircraft and sea craft for action. Once a submarine or other naval vessel received its targets, it would program a Tomahawk Land Attack Missile (TLAM) to destroy the target. TLAMs are only GPS programmable and have no way of distinguishing a decoy from the real target. One TLAM costs around $1.2 million (Thompson, 2000). If the target was given to a B-52, it would then utilize a Conventional Air Launched Cruise Missile (CALCM). This type of missile is similar to the TLAM and costs approximately $1.9 million dollars (Johnson & Meyeraan, 2003). According to the Kosovo/OAF after action report from Congress:

> Cruise missiles were used extensively in the first few days of OAF and during the periods of adverse weather. These weapons were selected to match NATOs campaign strategy. In particular, the desire to limit the exposure of manned aircraft in the threat area, as well as the need to minimize collateral damage, made cruise missile employment a logical choice. . . . Sea-launched and air-launched cruise missies (TLAM and CALCM) . . . provided the capability to penetrate enemy air defenses and attack a wide spectrum of targets throughout the battlespace (U.S. DoD, 2000).

As stated above, only 24 of the 78 days were clear enough for aircraft to drop bombs on targets. This meant the initial part of the campaign and 54 other days must have been dedicated solely to guided missile attacks. When air assets such as the F-16 were utilized to attack ground targets, the pilots were able to identify the targets by sight, but could not differentiate a decoy from the actual thing. Pilots do have great vision but from 15,000 feet no one can accurately identify an actual asset from a fake without proper technical support. Additionally, pilot debriefings and gun camera video did not furnish the necessary detail that might have been obtained if the missions were flown at a lower altitude, for example, identification of secondary explosions on targets (Johnson & Meyeraan, 2003) Without proper Battle Damage Assessments (BDA) intelligence analysts were unable to determine the success of their attacks until national overhead systems could capture current BDA information (Johnson & Meyeraan, 2003)

Another form of deception utilized by Serbian forces was the integration of military convoys with those of displaced civilians. "This both disguised their movement and protected them from NATO aircraft as a result of NATO rules of engagement (ROE)" (Johnson & Meyeraan, 2003). This deception technique provided the Serbians with a powerful media weapon. Even if a convoy of troops was properly identified and destroyed, the Serbian army would place bloodstained dolls amongst the casualties to amplify the fact that NATO was killing the innocent (Thomas, 2000). Whenever the international media photographed a site like this, the footage would put undue pressure on campaign efforts. This pressure forced still more NATO restrictions on combat engagement and eroded support for the campaign.

Even though Serbian deception tactics were rudimentary at best, they were able to significantly increase the costs of the war and undermine NATO's credibility. If Serbian

forces had been able to implement tactics that were more technically sophisticated than the ones they did employ, there is no telling what the outcome might have been.

4. Campaign Results

The results of the Kosovo/OAF campaign were ambiguous. Since Serbian deceptions were widely utilized, and accurate assessment of the situation has never been accurately reached. According to the Chairman of the Joint Chiefs of Staff, General Henry Shelton, the total strike assessment for OAF was 120 tanks, 220 Armored Personal Carriers (APC), and 450 artillery pieces (Johnson & Meyeraan, 2003) These figures were never verified. The Congressional after action report stated that their assessment provided in their report (shown in Figure 3) "provides no data on what proportion of the total mobile targets were hit or the level of damage inflicted on the targets that were struck. Instead, the numbers of target hits were collected" (U.S. DoD, 2000). This means that they can only verify having hit something, but there is no assurance that the numbers of actual targets destroyed are accurate. An article in "*Aviation Week and Space Technology* reported that NATO had dropped 3,000 precision-guided weapons that resulted in 500 hits on decoys, but destroyed only 50 Yugoslav tanks" (Thomas, 2000). Although the government was unable to provide an accurate account of the battle damage, independent reporters investigating the situation offered an entirely different assessment. Their assessments were done by driving throughout the countryside and taking a first-hand, on-the-ground look at of the destroyed targets. The following information was discovered:

> Indications were that only 13 Serb tanks and fewer than 100 armored personnel carriers had been destroyed. Reporters noted the ruins of many different types of decoys hit by NATO forces (e.g., rusted tanks with broken parts, wood or canvas mock-ups). Carlotta Gall of The New York Times, a veteran war correspondent from the first Russian war in Chechnya, saw little damage (Thomas, 2000).

Even after researching through many documents on the Kosovo/Operation Allied Campaign, I can find no data that refutes this independent assessment. There is even a report citing, the British Ministry of Defense saying "the damage done to tanks was even less than the lowest quoted figure of 13 tanks killed" (Thomas, 2000). Corroboration may also come from a comment given by a soldier who went into Kosovo after the air

campaign was over. As he said; “The only thing I know is that there were hundreds of Serbian tanks, artillery, and anti-aircraft weapons in convoys leaving the country as we entered it.”

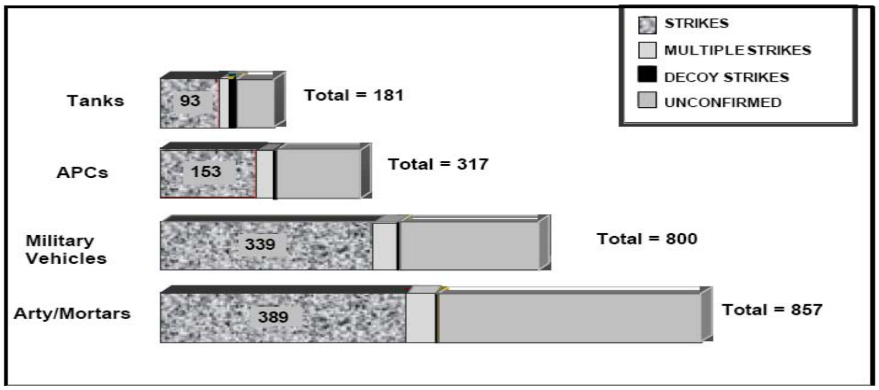

Figure 10. Strike Assessment Results for OAF

Even though there is no real assessment of the damage inflicted on Serbian forces there is a lot of information on what it cost. The Congressional report states: “six ships and three submarines from two U.S. Navy battle groups and one UK submarine launched 218 missiles in preplanned and quick-reaction strikes” (U.S. DoD, 2000). This means in TLAMs alone cost NATO and America over $216 million. Not to mention the $2.5 million per day cost to maintaining operations of each naval battle group within the area. Two battle groups costing $2.5 million per day times 78 days equals $195 million. An additional 80 CALCMs were deployed from B-52s. Just the cost for CALCMs was over $152 million, not to mention the costs of flying a B-52 and its crew to the proper destination in order to launch the weapon system. The TLAM and CALCM efforts in OAF depleted the whole NATO inventory and resulted in the approval of a defense spending request of $1.4 billion to replenish the stocks (Office of Secretary of Defense, 1999). One evaluation found online reports that the Kosovo/OAF campaign cost approximately $1 billion per month in 1999 dollars (Wilkins, 1999).

Even though General Wesley Clark’s primary concern was not to risk his pilots’ lives in combat, the campaign resulted in two aircraft shot down. One aircraft was an F-16 Fighting Falcon and the other an F-117 stealth fighter. These downed aircraft required an increased risk of life to save the downed pilots. According to Major Kent Landreth,

lead pilot during the downed F-16 rescue mission, “we needed to send a rescue team of three H-53 helicopters and 39 people to get the one pilot out” (Kent Landreth, personal interview, July 16, 2006). Search and Rescue teams are required to extract downed pilots from harm’s way. Each team contains helicopters that must fly at low levels to drop off teams of highly trained personnel that must search for the pilot. One manned aircraft being shot down places dozens of individuals at risk. Fortunately, the pilots from both crashes were saved and minimal damage occurred to the rescue teams

NATO and America were able to stop Milosevic and his troops from committing atrocities in the Balkans. However, it does not seem that they were able to inflict heavy damage on Serbia’s capacity to wage war in the future. According to the evidence, it seems the damage to the Serbian army was minimal and NATOs reputation degraded as an effective fighting force. This raises the question: Was the $1 billion a month cost worth it? Many people do not think so. I, personally, feel that a campaign to stop ethnic cleansing is worth every last penny a nation can spend. However, I feel that the money should be spent in a way that will best meet the demands of the cause in the least costly way available. Utilizing million dollar cruise missiles to destroy a $50 decoy is not money wisely spent. Could there have been a better way to execute the Kosovo/OAF campaign without wasting so many tax payers’ dollars and risking life? In the 90’s there may not have been. Unmanned Combat Aerial Systems (UCAS) were just a dream. Drone technology did exist but the technology to properly utilize drones to fight a war did not. If one was to take the Kosovo/OAF campaign and put it in the year 2009, then the answer to the question would have been YES. A drone F-16 utilized as a combat vehicle could have changed the conduct and outcome of the campaign significantly.

D. THE F-16 UAS

The campaign in the Balkans may have been fought the best possible way with what leaders had available at the time, but it was also the perfect environment for the use of UASs.

1. Limitations

Self-imposed limitations were the biggest factors that affected NATO's effectiveness and provided Serbian troops the means to deceive. General Clark's primary concern was the safety of his pilots. His concerns are the reason why there was a 15,000 foot limitation on all manned aircraft in the combat zone. This limitation made it almost impossible for pilots to locate and identify actual militarily valuable target. Since drone aircraft are flown without an on-board pilot, this limitation could have been avoided. The pilot of an Unmanned Aerial System flies from a secure location miles away. Requirements like target identification and destruction are carried out by a team of trained individuals. This alleviates the pilot from having to have visual contact with the target before it is destroyed. His only concern is to fly the drone The target acquisition teams have the luxury of utilizing special sensors that can be mounted on a drone. Without going into too much detail, these sensors can have a high capacity for zoom, infrared capabilities (to look for heat signature), night vision, and possibly Measurement and Signatures Intelligence (MASINT).

> Measurement and Signatures Intelligence is scientific and technical intelligence information obtained by quantitative and qualitative analysis of data (metric, angle, spatial, wavelength, time dependence, modulation, plasma, and hydromagnetic) derived from specific technical sensors for the purpose of identifying any distinctive features associated with the source, emitter, or sender and to facilitate subsequent identification and/or measurement of the same (Pike, 2000).

With these types of capabilities, analysts have the ability to find the target and verify its authenticity without the pressure of fatigue and the requirement to control the aircraft. Once the target is properly acquired and confirmed as authentic (not a decoy) with real time information, the destruction of the target can be confirmed. According to Major Christopher Gough, Aviano AB F-16 pilot in Operation Allied Force; "destruction of a target was fairly simple. The overriding issue was finding and identifying the targets" (Christopher Gough, personal interview, July 17, 2006). A system that is on most combat aircraft called LANTIRN (Low Altitude Navigation and Targeting Infrared for Night) has the capability to hit a target from 25,000' via laser guidance. Drones with this type of technology could have easily avoided the deception tactics utilized by the

Serbian armies whether they were at low altitudes or above 15,000 feet. Real time video would have prevented Serbian troops from replacing actual targets with decoys.

One other limitation that has not been discussed was the rule imposed by politicians. "Aircraft were not allowed to land with unexpended ordinance on board" (Thomas, 2000). This would be far less of a limitation to a UAS. UASs have no real reason to land except to re-fuel and obtain more ordinance. Manned aircraft have to land because of the pilot's physical limitations. Without a pilot, and with the ability to utilize air-refueling assets, a drone can stay in the air for virtually an unlimited amount of time. So, if there was a rule that the aircraft could not land until all its ordinance was expended, the drone could literally stay in the air until it had identified and destroyed as many targets as weapons on board. This benefit would have prevented wasted ordinance being dropped into the Adriatic Sea and lowered the number of sorties required.

2. Environment

Pilot fatigue, weather, and the mountainous terrain played a significant role in the Serbian's deception campaign. A great advantage of UASs is the lessening of pilot fatigue. Since multiple F-16 UASs could be flown by one pilot, dozens of F-16 UASs could be flown to a certain destination. Once the pilot positions these F-16 UASs, he could get out of the drone control cockpit and dozens of fresh pilots could replace him to individually fly each drone for re-fueling and combat. Once combat is completed, only one pilot would be required to fly them back.

According to Major Gough; "The weather is always a factor in air campaigns, and certainly, Kosovo's rugged terrain presented challenges. However, it was not bad enough to cause too much of a hazard for us to complete our mission" (Christopher Gough, personal interview, July 17, 2005). The LANTIRN system could have easily guided the pilots through the bad weather and terrain. The biggest problem with the weather was the requirement for the pilots to visually identify the target. As discussed in the limitations section, the cameras would have eliminated this factor.

3. Battle Damage Assessment

With the ability to properly identify and destroy targets, drones would have provided an accurate count and detailed videos of the Serbian assets destroyed. With this type of evidence, the Serbian campaign to thwart NATO would have been limited significantly.

4. Search and Rescue

Search and rescue teams will always be required to help those in need. However, drones may make search and rescue teams an obsolete requirement for downed combat pilot. There is no need to risk a team of 30 plus individuals to save a downed UAS. If a UAS is shot down, the only loss is a piece of equipment that can be remotely destroyed.

E. SUMMARY

During the Kosovo campaigns, UASs could have easily saved the American government and NATO billions of dollars and significant embarrassment. They would have been better able to overcome Serbian deception techniques, and would have prevented both the waste of ordinance and unnecessary post-flight expenditures. The F-16 UAS would not have been hampered by the many limiting factors placed on combat pilots during the operation and could have helped provide an accurate battle damage assessment. It is clear that the Kosovo/OAF conflict points to UASs as the best option for an inexpensive, low risk, high impact weapon system in future operations.

V. THE ETHICAL DILEMMA

War is a cowardly escape from the problems of peace
—Thomas Mann

A. WHAT ABOUT ETHICS?

Ethics is a critical subject when it comes to unmanned, autonomous, or robotic systems. Many scholars feel that developing systems that have artificial intelligence capabilities a kin to creating a new type of life form. If these systems are considered a life form then is it ethically acceptable to program these systems to do the dirty work for humans against other humans? Scholars feel this is a type of artificial slavery. While these debates continue to be discussed, the F-16 UAS is not an autonomous system and is under human control during the entirety of its combat mission. Never the less there are other ethical concerns.

1. Diplomacy

According to the Secretary of Defense UAS mission roadmap, unmanned weapon systems represent the future of war. They will reduce the risk to pilots' lives to zero, significantly decrease defense spending, and take accuracy and capabilities to a new plateau. However, in an effort to capture all the advantages and disadvantages of unmanned technology I find the biggest possible disadvantage could be political ethics.

This problem should not be overlooked. Since unmanned technology reduces the risk-of-life decision to zero, will the effort to seek peaceful solutions also be reduced? Going to war is a very difficult decision because a nation must weigh its options. It must decide whether risking the lives of its citizens is worth the principles or issues being fought for. This decision process and its negative consequences is what make countries seek peaceful solutions. By employing unmanned technology in wars diplomacy might conceivably become a thing of the past. If there is no risk of losing lives, war could be an easier decision. There are no negotiations to worry about. Conflict could become an all or nothing endeavor.

2. Superiority

We were defeated by one thing only —
by the inferior science of our enemies.

—Arthur C. Clarke

America is currently engaged in multiple wars in Iraq, Afghanistan, and a global war on terrorism. According to John Arquilla, Professor of the Naval Postgraduate School, "It seems that the Department of Defense feels each of these wars can easily be won through advanced technologies" (lecture, 2006, July 11) . Billons of American tax dollars are being spent on research and development in advanced weapons systems, like the F-22 and F-35 fighters. These two programs are only the pinnacle weapons systems being developed for the Air Force. The other military branches have their multi-billion dollar weapons system projects too. America is so focused on developing tools of the future that it is forgetting the here and now. Warfare in the future may well need a system like the UCAV. A fleet of UCAVs by 2030 is in my opinion, a very admirable goal. America should continue to work toward this goal. One never knows what the future will hold. A UCAV force may just be what is needed in future warfare. However, spending billions of dollars on a transitional weapon system like the F-22 is is hard to justify. Even though American air power is threatened by surface-to-air weapon systems and hand held anti-aircraft systems, it is still the most powerful force in the world. No country can currently challenge America's power for airspace control. The Department of Defense needs to accept a plan that will maintain a good enough status until the UCAV fleet becomes operational.

This good enough process allows our country to take advantage of low cost advancements in current technology. Precision bombings are something that is needed in all the wars in which America presently engaged. However, is precision bombing going to require an advanced weapon system like the F-22? None of our current adversaries have an opposing force that can come close to challenging American air superiority. For this reason the F-16 UAS is the perfect interim solution. The F-16 is a current technology that needs only a few advancements to sustain our Air Supremacy edge until

the UCAV fleet is operational. By converting the F-16 UAS the United States Air Force could develop a fleet of weapon systems that would be easily adequate for the tasks at hand, while reducing the military budget by tens of billions of dollars over 25-years. This savings could be re-routed to fund a host of other working projects.

We should be mindful that a preoccupation with developing superior technology was also the route taken by the German Nazis. They were excessively fixated on developing technologically advanced weapons that did little to improve their strategic situation. Their "V-weapons program cost over 5 billion marks, and absorbed tens of thousands of workers. The resources that went to build them could, according to the American Bombing Survey, have produced an additional 24,000 aircraft" (Overy, 1995). According to John Arquilla; "The whole Nazi fleet only had a little over 2000 aircraft. Imagine what it could have done with an additional 24,000" (lecture, 2006, July 11). If the German military did have an additional 24,000 aircraft the possibilities are frightening. Fortunately for us, while the German scientists pioneered the world's most advanced weapons –rockets, jets, atomic weapons-its forces lacked adequate support to fight the war in which they were engaged (Overy, 1995). They spent billions of marks on projects at the very frontiers of military science which brought almost no advantage (Overy, 1995). "The paradox can be explained in part by the warped outlook of Germany's leaders, who persuaded themselves as the war began to turn against them that German science could conjure up a new generation of fantastic weaponry that could reverse the war's course at a stroke" (Overy, 1995). The resulting approach was disastrous.

One can only hope that the Department of Defense is not walking the same road. Hopefully, it is not so focused on developing dramatically superior weapons that it loses track of the wars at hand. Additionally, one must remember that technological advancement introduces both opportunity and vulnerability. No matter how inferior or superior ones technological base, it only needs the human mind to discover an innovative solution to countering it. The mind is and always will be the most innovative and powerful weapon of all.

3. Other

The greater the difficulty the more glory in surmounting it.
Skillful pilots gain their reputation from storms and tempests.

—**Epicurus** *Greek philosopher (341 BC - 270 BC)*

Flying an aircraft in battle is very romantic. The pilot who is able to survive the storm is a hero. There is little romance in flying an unmanned weapon system. The pilot gets into a simulator and safely gets back out. There is no danger involved. Romance may be the reason why governments are spending billions of dollars to create the perfect manned flying system. It may also be the reason why many individuals involved in the flight arena are so opposed to unmanned aerial platforms fighting the wars. Unmanned systems take away the glory. In WWII the German navy also felt this way about submarines. There was nothing sexy about submarines, so they did not produce them in sufficient quantities. However, the few submarines that they did have caused the most sea damage during the war. As Professor Arquilla notes, "the German navy spent over 80% of its budget on battleships" (lecture, 2006, July 11). The German navy was so bent on developing a glorious naval fleet that it overlooked its most powerful navy asset. Imagine what the German navy could have done if it spent its budget on submarines instead of battleships. It may have won the war. However, the glory of having a huge naval fleet proved the Navy's demise. The glory factor actually raises two separate ethical concerns; 1) Is it ethically right to use unmanned weapons systems against people? 2) Is it ethically right to deny the development of inexpensive unmanned systems to satisfy personal desire? Hopefully, American leadership can properly tackle ethical concerns in mitigating the glory factor.

B. SUMMARY

Such ethical concerns may be nothing or it may be everything. There are theoretical horrors that could undermine the development of unmanned weapon systems. No matter how easy war becomes by utilizing unmanned weapons they still kill. The difficult road to seek peace is and always will be the best solution. One can only hope that intelligent individuals are working on solutions to these ethical dilemmas instead of

worrying about the rights of artificial life forms. The superiority concern makes one wonder why must the superior technology always be sought. Why can't we find and utilize the best solution for the situations at hand. Will the superiority factor contribute to America losing the wars of today? Only history will tell.

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VI. CONCLUSION

The F-16 UAS is an alternative solution. It is a system that will allow the United States Government to maintain Air Supremacy until a UCAV fleet is operational. It can provide an increase in current weapon system capabilities, reduce the risk-of-life factor to zero, decrease budget costs, and allow technological advancements on an old airframe. Chapter I provides an overview of unmanned technologies and their advantages as well as their disadvantages. Chapter II provides a cost comparison of the F-16, F-22 and the F-16 UAS. Chapter III provides an analytical view of the F-16 UAS through the Nash Arbitration model. The Nash Arbitration model suggests that the F-16 UAS is a good compromise and has the ability to increase the American government's air power significantly further than the F-16 and F-22. The savings outlined in Chapters II and III do not even consider the budget costs saved from other areas of significance. These areas include reduced search and rescue requirements, cruise missile productions, carrier fleet operations costs, and a number of other reductions. Chapter IV suggests that the F-16 UAS could have increased the success of the Bosnian/OAF situation. Finally, Chapter V provides a few ethical concerns to be considered before the American government can truly decide whether the unmanned aircraft decision is the proper course for the future.

In an overall assessment, the F-16 UAS is an inexpensive, highly advanced solution for American air supremacy. One could only hope that the United States government is willing to spend a few million dollars in developing the F-16 UAS to test this thesis' hypothesis. The results may or may not be the answer to deploying maximum airpower at minimum cost. However, if the F-16 UAS is never built, the answer to the solution of an interim weapon system may never be properly answered.

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